A New MEP Method in Modeling Water and Energy Cycle Variability at Regional to Global Scales

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Summary

The maximum entropy production (MEP) model of heat fluxes has been further applied to modeling watershed evapotranspiration (ET), land and ocean surface energy fluxes, and intra-seasonal MJO processes. The MEP model predicted ET agrees closely with the observations using fewer input data than classical methods. The MEP model produces the first radiation energy constrained global surface energy fluxes including the new ocean/snow/ice surface heat fluxes. The XXX model coupled with the MEP model of surface energy budget produces much enhanced MJO signals. These case studies demonstrate the potential of the MEP model in the study of water and energy cycles at local to global scales.

Formulation of MEP Model

A) Latent E, sensible H and ground/ocean heat flux Q are solved as the partitioning of surface radiation fluxes (Wang and Bras, 2011, Wang et al., 2014):

$$\left[1+B(\sigma)+\frac{B(\sigma)}{\sigma}\frac{I_s}{I_0}|H|^{-\frac{1}{6}}\right]H=R_n$$

$$E=B(\sigma)H$$

$$Q=\begin{cases}R_n-E-H & land\\ R_l^n-E-H & water, snow, ice\end{cases}$$

$$B(\sigma)=6\left(\sqrt{1+(11/36)\sigma}-1\right)$$

$$\sigma=\frac{L_v^2 q_s}{C_p R_v T_s^2}$$

R_n: net radiation ($W\ m^{-2}$)
R_l^n: net long wave radiation ($W\ m^{-2}$)
L_v: latent heat of vaporization ($J\ kg^{-1}$)
R_v: water vapor gas constant ($J\ kg^{-1}K^{-1}$)
C_p: specific heat of air ($J\ kg^{-1}K^{-1}$)
q_s: surface specific humidity ($kg\ kg^{-1}$)
T_s: surface temperature (K)
I_s: thermal inertia of Earth's surface (tiu)
I_0: apparent thermal inertia of the air

Net surface heat flux is defined as

$$R_n-E-H=\begin{cases}Q & land\\ R_0+Q & water, snow, ice\end{cases}$$

$R_0=R_s^n$ = net shortwave radiation ($W\ m^{-2}$)

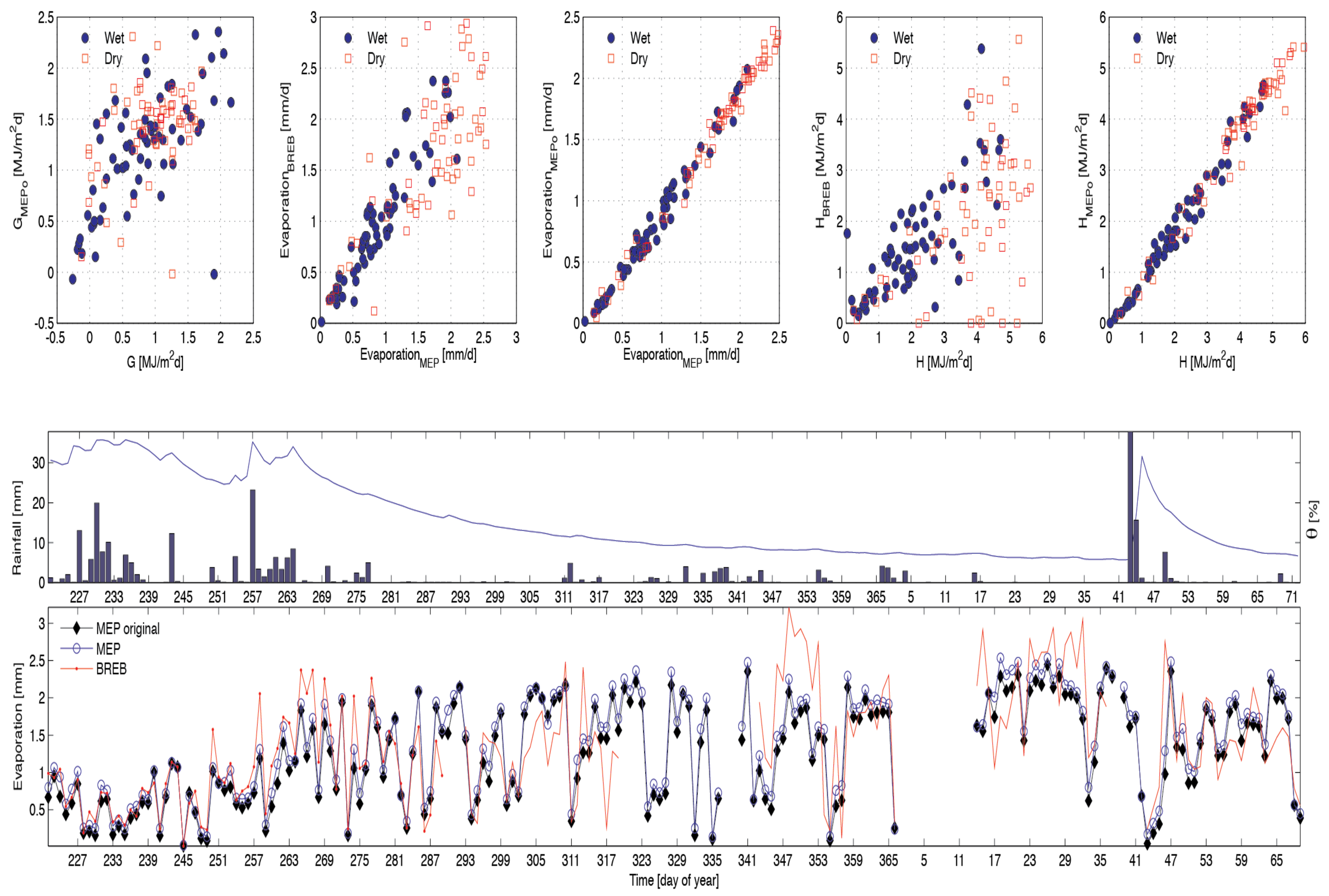
B) Model Input

Land: R_n, T_s, q_s Ocean: R_n, R_n^l, T_s

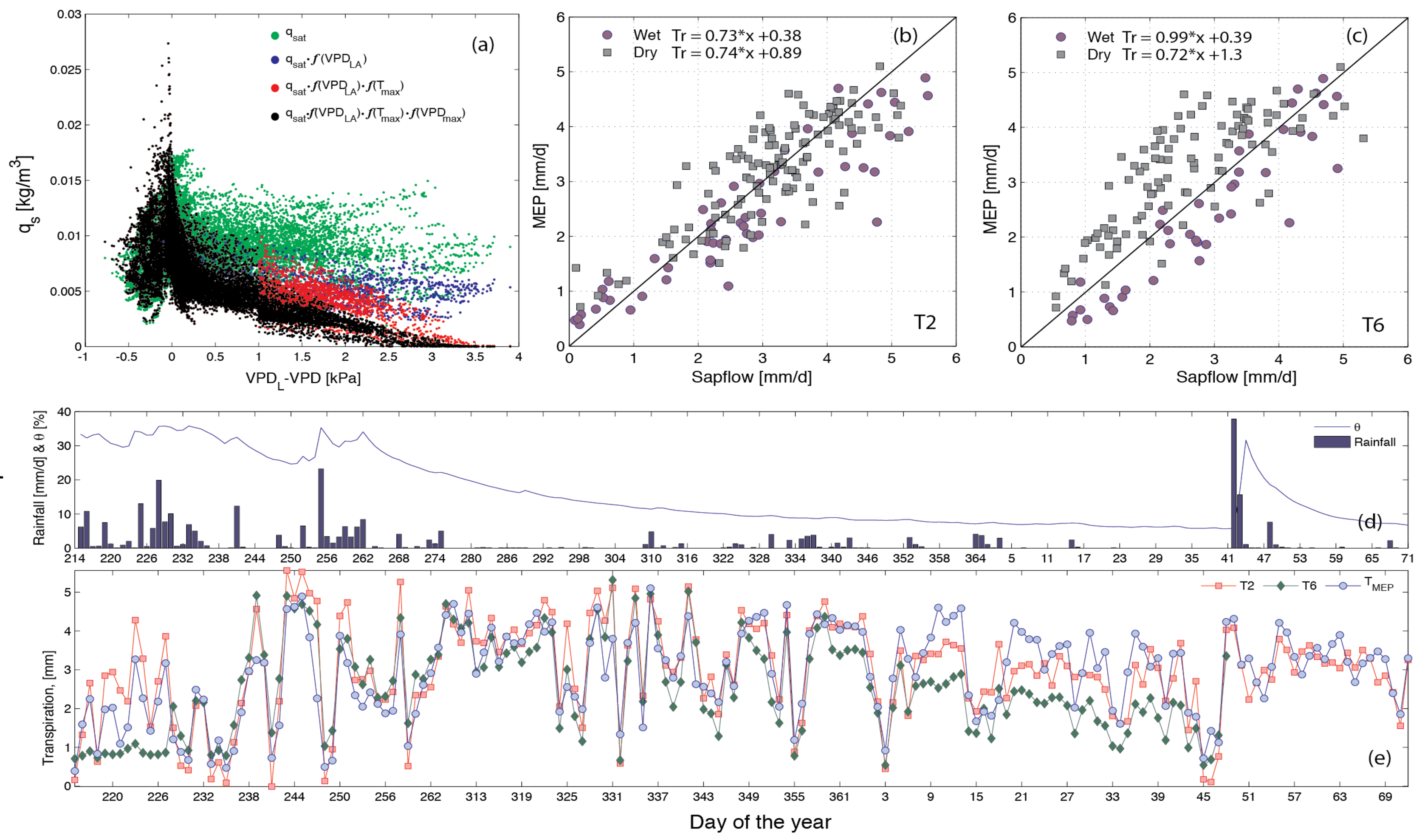
C) Properties of the MEP Model:

- **closing surface energy budget;**
- **not using bulk gradients of vapor pressure and temperature as model input;**
- **not explicitly using wind speed and surface roughness as model parameter.**

Modeling Watershed Evapotranspiration (Gutierrez-Jurado et al, 2015)

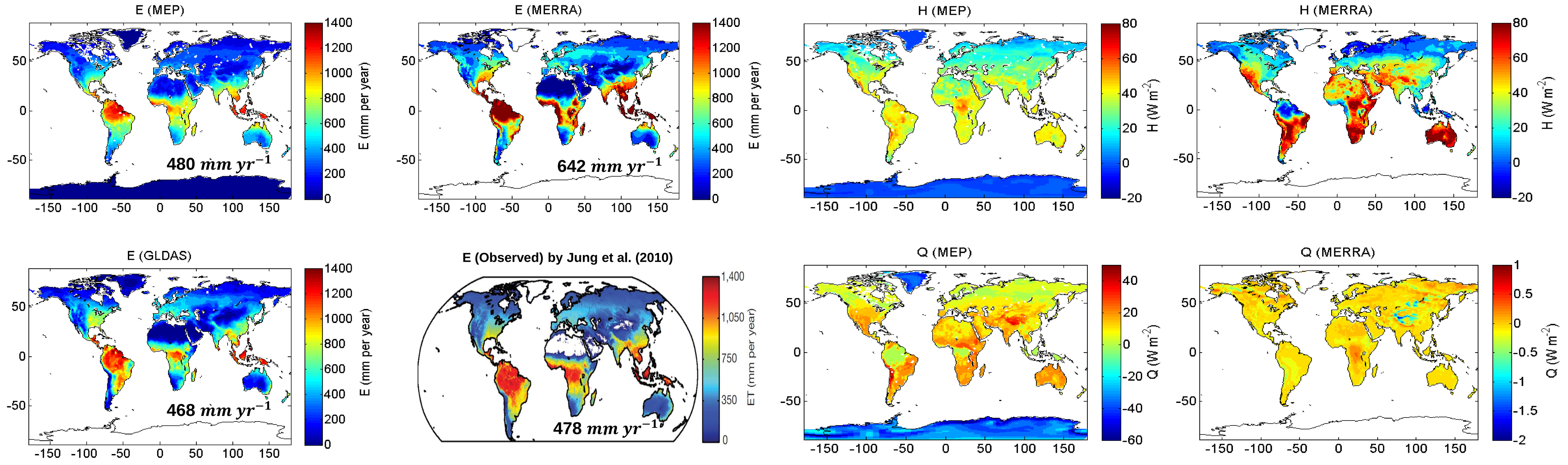


Left Panels: MEP modeled vs observed (Bowen Ratio Energy Balance System) ground heat flux G, soil evaporation and sensible heat flux H at a sparsely vegetated site over a complex terrain.



Right Panels: MEP modeled vs observed (sap-flow) plant transpiration and H at a dense vegetation site over the same terrain.

Global Surface Heat Fluxes (2001-2010) (Huang et al., 2015)



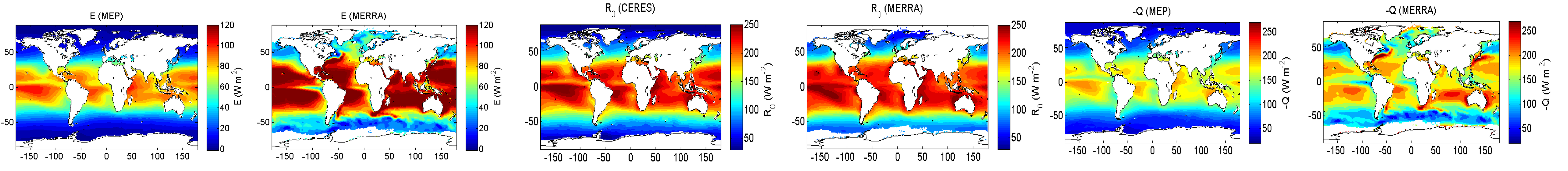
MEP modeled annual means of the global surface heat fluxes using the NASA CERES surface radiation, temperature data supplemented by surface specific humidity data from the MERRA reanalysis.

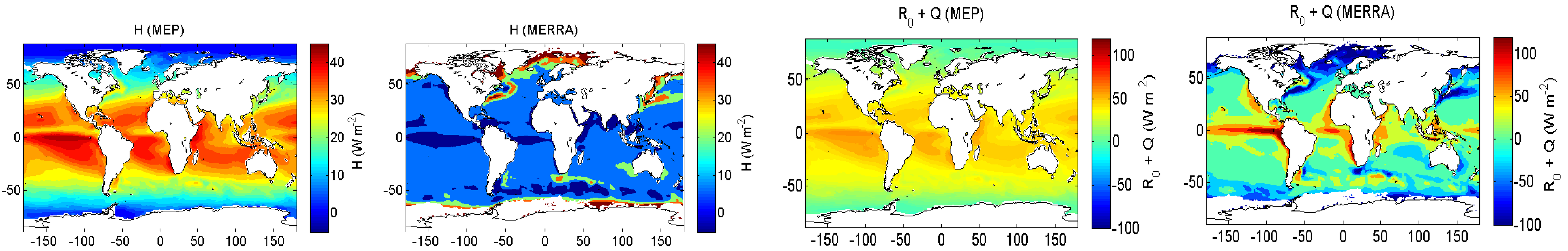
Validation

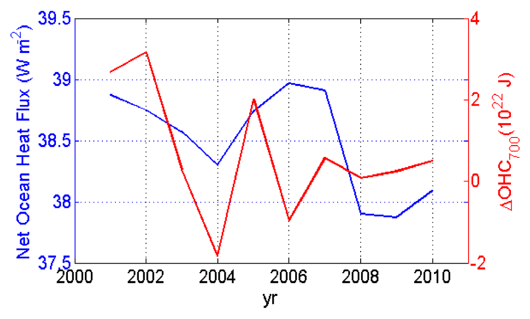
Model Input

Model Input	Data Products	Resolution: Spatial	Resolution: Temporal
R_n, T_s	NASA CERES	$1^o\times1^o$	3-hourly
q_s	NASA MERRA	$1^o\times1^o$	3-hourly
Land Cover	IGBP	$1'\times1'$	–

Data Set	Resolution: Spatial	Resolution: Temporal
MERRA	$1^o\times1^o$	Monthly
Global Land Data Assimilation System (GLDAS)	$1^o\times1^o$	Monthly
National Oceanographic Data Center (NODC)	$1^o\times1^o$	Monthly



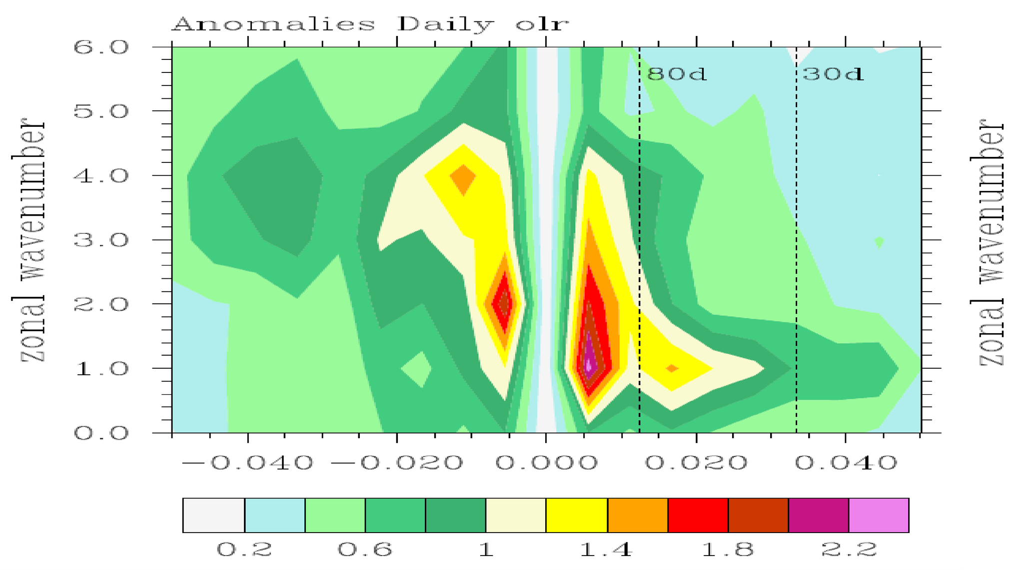


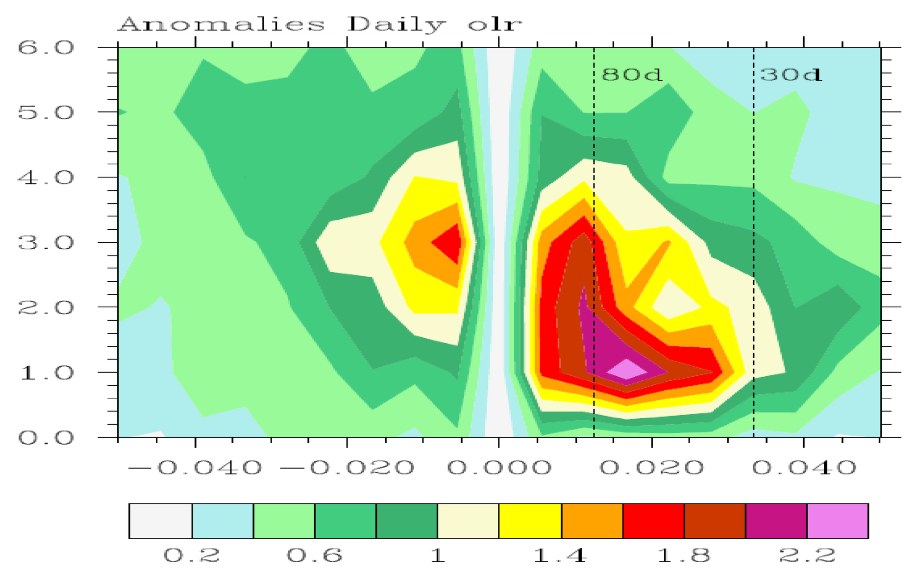


Net ocean heat flux R_n-E-H (R_0+Q) and the change of ocean heat content (ΔOHC) from National Climatic Data Center (NCDC). The correlation coefficient is 0.4

Tropical Madden Julian Oscillation (MJO)

The MEP-based surface flux models are used as new surface heat flux parameterizations in the NCAR CAM5 model. Left panel: the MJO signature in the time-space spectrum of the tropical OLR (zonal wave number 1 and 30-80 day period) in the default CAM5. Right panel: the MJO signature in the time-space spectrum of the tropical OLR in the CAM5-MEP. A significant increase of the MJO variability is found when the MEP-based parameterizations are used.





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Acknowledgments

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